

Ms. P268²²⁶ - 1907

ON THE
METHOD OF STUDYING
A
NATURAL SCIENCE
SUCH AS
PHYSIOLOGY.

An Introductory Lecture, delivered October 9th, 1894.

BY
WILLIAM RUTHERFORD, M.D., F.R.S.S.L. & E.,
PROFESSOR OF PHYSIOLOGY, UNIVERSITY OF EDINBURGH.

(Reprinted from the Edinburgh Medical Journal for November 1894.)

PRINTED BY OLIVER AND BOYD, EDINBURGH.

MDCCCXCIV.
2

ON THE METHOD OF STUDYING A NATURAL SCIENCE SUCH AS PHYSIOLOGY.

WE are assembled here for the study of Physiology, and it will be of service if, at the outset, I indicate the method of study that will best aid you in its pursuit.

It is our duty to help you to obtain an accurate knowledge of the main facts and theories of physiological science; to assist you in obtaining a knowledge of physiological facts, as far as possible, by your own observation; to enable you to understand the methods that have led to physiological discovery; to induce you to criticise physiological theories, and thereby cultivate a habit of independent thought; to enable you to perceive how, in some cases, we can pass from that which is known to a conception of what is probable in regions that are unknown, and so stimulate you to a scientific use of the imagination, tending towards the formation of ideas that may, in the future, serve to open up new fields of inquiry and lead to discovery.

Such is a brief outline of what must always be the programme of a real education in any science whose data have—like those of physiology—been arrived at by observation and experiment. You naturally desire to know the best methods by which you can gain such knowledge of natural science, and undergo such mental training as will enable you to think for yourselves on scientific subjects, and feel that you can place reliance on your own conclusions. You will find considerable variation of opinion in different schools regarding the methods to be adopted, and you will find that these different opinions chiefly relate to the value of systematic courses of lectures as compared with tutorial teaching, reading, and practical study. Having been a teacher of science for now thirty years, and having studied in several schools in different countries, I hope I may have earned some title to pronounce an opinion on the method of scientific education.

The primary requirement of the student is the creation of an intellectual atmosphere, in which his mind can work efficiently

and with comparative ease. The mere attendance at a school or university goes far to create such atmosphere. But a general atmosphere is not enough; there must be the creation of a special atmosphere in every subject of study. There is no method by which this special atmosphere can be so readily and so fully created as by a systematic course of lectures on the subject of study. It is the duty of a lecturer to condense the subject he teaches, and to present it to the student in strict logical order, so that he may be led step by step from the simple to the complex, by, so to speak, a natural process of development. The order of statement is all-important. The most difficult subjects can be rendered intelligible if the order of statement be carefully considered, so that the mind shall be led by easy gradation and logical sequence.

An inexperienced student may imagine that if the lectures were printed verbatim, and privately read, their perusal would enable him to learn the subject quite as well as attendance at the lecture. But the result of the two methods can never be the same. The mental atmosphere created by reading a difficult subject is always comparatively dull, and in young minds it is apt to become repulsive. Although reading is, of course, an essential adjuvant to a course of oral instruction, it can never adequately supply its place. Silent words, however well arranged to convey lucid ideas, can never arrest the attention and stimulate the mind as spoken words are capable of doing. Who has not felt how great a difference there is between reading Shakespeare's plays and seeing them acted on the stage? Even when they are simply read aloud by a single reader who understands the significance of each passage, and gives suitable emphasis and modulation, how much more the mind is stimulated by such living recital than by perusal of the silent words. We must recollect that words are but symbols of speech; only when spoken do they become endowed with their fullest life, and penetrate readily the inmost recess of the mind. No silent page can give the lights and shades of expression thrown upon any subject by the varying emphasis and inflection which they naturally receive from the speaker. Even in scientific description, words receive new meaning when spoke by one who understands the subject and desires to convey its significance to others.

But the mere fact of assembling together for the purpose of being collectively addressed is itself of value. Man's sympathetic nature renders him gregarious. He is happiest when he feels himself in sympathy with others. He naturally draws towards those whose mental features and pursuits are similar to his own, so that he may enjoy a congenial atmosphere. In young minds this desire for sympathy is conspicuous. Therefore it is that the sympathetic influence pervading a class-room can induce mental effort in a manner congenial, because harmonious with innate

feeling, and in a manner differing from the stimulating influence of rivalry that comes powerfully into play at the same time. The desire for sympathy and love of generous rivalry fan the young mind into the mental glow we call enthusiasm, that is so great a help in study; it lightens labour; it carries the mind up difficult paths to high attainment; and therefore it is our duty to do what we can to foster a spirit so helpful.

Physiology is an experimental science, and must be taught experimentally. In former times, when courses of lectures were given by physicians busily engaged in practice, the lectures were scarcely at all illustrated by experiment, because the lecturer seldom had a laboratory and a suitable collection of apparatus; and he had no time to prepare elaborate experiments. Happily nowadays all that is changed, and far greater care is taken to teach physiology in such a manner that the student's interest may be awakened and his mind really educated in the science. Experimental illustration of lectures is essential in order that the student may realise the methods by which physiological knowledge has been arrived at. The nature and arrangement of the apparatus, the steps of the experiment, the difficulties encountered, the devices by which they are overcome, the inferences to be drawn, and the fallacies to be guarded against,—all stimulate him to feel an interest in the subject and furnish him with a *real* knowledge of an experimental science. It may perhaps be as well to say that the great majority of the experiments required for the illustration of physiological lectures are not experiments on living animals. Most of them are experiments of a physico-chemical nature. Many are experiments on living *tissues*, but only a small number consist of experiments on living animals, and they are performed without producing pain.

Some of you will ask if you should read up a subject in a text-book before hearing it lectured upon? To such a question I give the unhesitating answer—first hear the lecture and then read. The lecture easily creates the mental atmosphere you require to enable you to read with full advantage. When you read the subject after listening to a lecture upon it you will find that you can recall much of what you saw and heard, and that you can grasp and assimilate the subject far more readily. But if the readiest way to learn a science is first to hear it lectured upon and then to study it by reading piece by piece, it must be to your advantage that the course of lectures should cover the whole subject. That is the principle adopted in the Scottish Universities, and I am convinced it is the method best fitted to help the student.

You will ask, What shall we read? To that I answer without hesitation—first read your notes of the lecture, and then if you so desire, read a text-book; but first read your notes, for they will recall the lecture and keep you in the same line of thought until you have mastered what they contain. The mention of *notes*

awakens the vexed question of note-taking. Those who can write shorthand have no difficulty. If I had known the value of shorthand to every medical man—and, indeed, to every one who has much writing to do—I would certainly have learned it in student days, and I would advise every one of you to learn it while you are still young enough to acquire it readily. But those who can only write in longhand can take sufficient notes if helped by a syllabus containing some short notes of the lectures. A syllabus is essential. It shows in perspective the arrangement of the subject, and is a great help to the teacher as well as to the student. I would recommend all to take notes, not merely because of the condensed information they will contain, but because note-taking greatly helps to fix the attention on the subject. All minds, but especially young minds, find it difficult to concentrate the attention and keep it steadily fixed on the subject under discussion. In scientific exposition it is essential that the attention of the listener shall be continuously applied; otherwise the thread is broken and its gaps cannot be supplied by any effort of imagination. Scientific exposition does not consist in statements strung together in irregular order, but in continuity of idea.

In reading scientific subjects I would recommend you always to read *very slowly* and deliberately, so that you may allow due time for the production of a sufficiently deep impression on the memory. In this age of haste we all tend to read too rapidly. The mind tends to be hurried along the lines by the “frenzied current of the eyes,” with the result that the mental impressions are so confused and mixed that the memory cannot accurately recall them. You see this illustrated every day by the manner in which people read a newspaper. They diligently scan its columns for half an hour or more; they may read so much in a short time that the rapidly succeeding impressions efface each other, and you may discover that they are unable to give you any definite and accurate account of any topic they have been reading. I am certain that the first thing many students have to learn is how to read with advantage. When the student of anatomy begins with a bone in one hand and a book in the other in which every feature of the bone is described, it may seem easy for him to read with advantage; but it is not so. Some days or even weeks may elapse ere he discovers how vividly his attention must be fixed on the subject, and how carefully he must seek to verify every sentence in the book with the object it describes. Reading with a view to learn anything of importance must always be slow enough to allow time for thought. By far the most important part of study is the thought by which it is accompanied. Thinking much on what we learn by the senses is real study. Mental digestion and assimilation are impossible without thought. The mere accumulation of facts undigested by thought is the process termed cramming. The knowledge so gained is

evanescent and of little permanent value, because it is unreasoned knowledge. Scientific education may be defined in a single sentence as the acquirement of reasoned knowledge. No man can learn physiology unless he thinks much and deeply. No flippant superficial mind need hope to master even its main principles. At every step mental insight is necessary. Therefore it is that the thinker wins the highest place in the study of physiology, as he eventually does in the practice of medicine.

But before I pursue this topic further, I may allude to the tutorial method of teaching.

The tutorial method is extremely useful as a supplement to some systematic courses of instruction. It is essential when anatomical objects or physiological apparatus have to be demonstrated to small numbers at a time. It is valuable for the revisal by question and answer of the instruction given in systematic lectures; but when it is used as a substitute for systematic courses of lectures, as is the case to so large an extent in the older English universities, the result is not to the permanent advantage of the student. We must bear in mind that to pass an examination is not the ultimate aim of education. The rapid storage of the student's mind with numerous facts and imperfectly discussed theories is not the education that will render him a reliable and independent thinker in after-life. The tutorial method usually tends to degenerate into what is termed "grinding." The method is hostile to that sustained exposition which is the distinctive feature of the lecture, that lifts it far above tutorial instruction as a method for expanding the mind and educating it in the method of scientific exposition and study. Many a student eventually becomes an expositor of scientific and other subjects; and he is educated for such duties by listening to sustained expositions in a manner which he cannot be by the tutorial method. I hope the day will never come when the systematic courses of lectures given in Scottish universities are to be curtailed and replaced by tutorial instruction. I believe that if such should ever come to pass, it will be because Professors have failed to keep their lectures in touch with the immediate as well as the ultimate requirements of the student. It is our duty to teach in such a manner that you be enabled with a fair amount of honest work on your part to pass your examinations; that is your immediate requirement; and as members of a university we are bound so to teach that your minds may be trained in scientific modes of thought, so that you may be enabled to rightly use the knowledge you have gained; that is your ultimate and highest requirement for the successful practice of medicine.

Let me now turn your attention to the value of practical studies.

Shortly summarised, their value consists in this,—that they bring the student into direct contact with Nature; they cultivate

his power of accurate observation, and they train him in manipulative dexterity.

All natural science springs from the observation of Nature. We can learn much by hearing and reading systematic expositions of the facts and principles arrived at by research. But it is at the same time necessary to take the student to the sources of such knowledge. The student of every natural science must be brought as directly as possible into contact with Nature, so that he may study phenomena directly by the use of his own senses. By such method of instruction the student is not treated as a mere absorber of the statements made in books and lectures, but as an independent observer requiring proof of the statements made, desiring to examine the structures described, to test the properties of things, and acquire the power of accurately observing and manipulating.

This practical study of Nature is attractive to all, but especially so to young minds. At any age—but especially in youth—the mind is apt to grow weary of abstract statements, and to lose touch with a subject so treated. The mind is not satisfied by mere descriptions of phenomena, but desires to realise them by direct inspection. This method of studying Nature by direct contact with it inspires a degree of confidence not otherwise attainable. The mind feels the support of solid ground and can advance with reliable step. When the student by this method criticises and tests anew the observations made by others, they become to him living impressions vividly imprinted on his mind by a natural method. But while the student soon perceives that the method of practical study is the surest way to acquire definite and lasting knowledge of scientific facts, he is at the same time, because of his eagerness to learn the concrete facts, apt to forget that a great and leading object of practical studies is to quicken and increase the power of making accurate and independent observations.

I need hardly remind you how greatly men differ in their power of observation. If you listen to travellers giving an account of the impressions they have received in the countries and cities they have visited, you find how much they vary in the use they have made of their eyes. Some have allowed little to escape their notice, others have only vague impressions of what they have witnessed. Some men have such power of concentration that they are able to fix their attention firmly on an object until they have thoroughly scrutinised it, and have obtained a deep and abiding impression regarding it. Such men apply their minds thoroughly to the subject on hand. They proceed methodically; they avoid flitting rapidly from one object to another, knowing that by such butterfly method an abiding impression is unattainable. On the other hand, there are many who have no firm grasp; their eyes are open, but they fail to see; their impressions are vague; they hesitate to describe them, because they cannot exactly recall them.

Every session we notice that when a number of students are examining similar objects with the microscope and are asked to describe what they see, they vary greatly in the acuteness and accuracy of observation. The cause of the difference is almost entirely mental; most men's eyes are good enough; it is the acuteness of their mental vision that varies so much.

Anatomy has always taken the lead in practical study. No man can sufficiently learn anatomy, and no one can become a surgeon unless he dissect the body to acquire a thorough knowledge of the relative positions of its parts, and the manipulative dexterity required to deftly use a scalpel and forceps.

In Chemistry there has long been a practical class, but in my student days no one gave us any systematic instruction in the practical chemistry which every medical man requires daily in his professional work. The late Professor Bennett began the teaching of Practical Physiology, and practical instruction in Physical Diagnosis in the Medical Wards of the Infirmary, but it has been only within the last twenty years that the example he set has been imitated in all the other departments of medical study. I can remember the day when men with fossilized minds sneered at the extension of practical classes as a new burden and tax on the student. Such blind leaders of the blind were ignorant of the methods by which young minds are to be rightly led into the domain of natural science. They could not perceive that the physician is a naturalist who must be intimately acquainted with Nature, knowing how to skilfully observe her manifold phases, and how to rightly influence them by various preventive and curative means.

Every one feels that the student of medicine in these times has far greater opportunities for learning the science and art of his profession than he had some twenty years ago. But amidst the multiplied opportunities now available for acquiring the habit of accurate observation and dexterous manipulation, I wish we could find reason for believing that students generally are as anxious to acquire the habit of thought necessary in medicine as they are to learn a multitude of facts for the day of their examination. We see all around us how rapid is the advance of medical science, and how impossible it is for any one mind to master all the minute facts of any one department. In view of the increasing complexity of medical science, which the student now strives to learn in five years, it becomes more and more necessary that in professional examinations we should be careful not to lead the candidate to suppose that his mind must be crammed with the ephemeral knowledge of a multitude of minute details. The time spent in striving to master too many details lessens the time required for thought, and tends to make the student a crammer instead of a thinker. What the student requires is a knowledge of the important facts and theories of each science, but his knowledge of these must

be *sufficient*, and *accurate*, and *well-reasoned*. He must show that he thoroughly understands the subject. And further, in view of this rapid advance, it becomes the more necessary that the teacher shall, in his course of lectures and practical study, become more and more *selective*, so that he may sufficiently guide the student in the application of his powers to the scientific topics of primary importance. No mind, young or old, should strive to become an encyclopædia of knowledge. Life is too short for such effort; and, assuredly, it can never be accomplished in five short years.

But while moderation in study and in examination requirement is now, and will, in the future, become more and more imperative. I would ask the student to remember that his brain, like his muscles, will not grow larger and more powerful unless it is urged to strong effort. An easy-going study will never fit you for the battle of professional life. No physical athlete could excel unless he voluntarily undergo long training in muscular efforts that lead to increase of his strength and endurance. No man can attack the many difficult problems of medicine unless he voluntarily submit to severe mental discipline and compel himself to forego pleasure, and live laborious days of strong effort to learn the chief facts of medical science, and train his mind in the necessary habit of thought. We have had good reason to conclude that in recent years a good many students of medicine have desired to be spared as much as possible the labour of study. They desire short cuts to knowledge, and to be spared the trouble of thinking for themselves. This undesirable mental attitude may serve immediate purposes, but it will never make a man a successful practitioner of medicine.

This leads me to return to the Importance of Thoughtful Study.

When you visit the Infirmary you find the physicians and surgeons daily called upon to examine the varied and complicated phenomena of disease. You will be struck by the infinite pains with which they minutely inquire into every fact that can throw light on the cause, and on the nature and extent of the disease. They carefully assemble all the evidence they are able to obtain; pronounce their opinion on the relative significance of the various symptoms, and resolve on the method of treatment. You will discover that what is termed "medical instinct" really consists in the possession of accurate knowledge; the power of making accurate observations; the faculty of acute insight, and of rightly estimating the relative significance of symptoms, so that a reliable decision may be arrived at.

The study of physiology is of special value in enabling the mind to acquire the habit of thought necessary in medicine. Chemistry, physics, and anatomy are each of great value in training the mind in scientific method and habit of thought, but it is the science that treats of the properties and functions of the tissues and organs of the body that unites the qualities of thought required in the pursuit of medicine. The value of physiology as a subject of

study lies not merely in learning important facts regarding the actions of the several parts of the bodily mechanism, but in the necessity for continuous thought on problems requiring keen insight and cautious judgment. The study of physiology is rendered difficult by the complicated nature of the bodily mechanism, and the hidden obscurity that veils the innermost workings of all vital processes.

The circulation of the blood is a fact so commonly known that the unthinking mind is apt to take its proof for granted. But few physiological processes have had so much thought devoted to them by a single mind as the motion of the blood received from Harvey. The student requires not merely to know that the blood moves in a circle, but he requires to ponder the reasons that led Harvey to prove that the blood *must* be regarded as moving in a circle, although he had no microscope to show him the blood flowing from the arteries to the veins through the capillaries. He requires to repeat Harvey's process of thought before he can realise how much we owe not only to his accurate observation, but still more to his power of inductive thought.

The movements of the heart, and the manner in which they are affected by various conditions; the manner of the blood-flow in arteries, capillaries, and veins; the several conditions that cause variation in its distribution to different organs,—these and other phenomena connected with this single province of physiology compel the student to exercise the kind of thought he will always require in medicine.

But physiological study implies not merely an understanding of its established laws, but also translation of thought from what is proved to what is probable. That implies a scientific use of the imagination,—that is to say, it implies that the imagined process shall seem probable, because of analogy with some process already known, or because of the necessity for framing the hypothesis to afford reasonable explanation of the facts.

Do not misapprehend the term *scientific use of imagination*. Science is not founded on imagination, but on facts proved by observation and experiment.

An unscientific use of the imagination developed the tangled thicket of weeds that so long hindered the growth of science. The old doctrine of Galen that the heart and arteries forcibly expand like a pair of bellows for the purpose of drawing blood into them, just as the expansion of the chest draws air into the lungs, is one of many examples of an unscientific use of the imagination. There is no real analogy between the expansion of the chest and the expansion of the heart; nor is there any analogy between the expansion of the heart and that of the arteries. Harvey's accurate observation and experiment entirely abolished Galen's unscientific hypothesis.

The physicist resorts to a scientific use of the imagination when

he supposes all space filled with an ethereal medium. He has proved that light must be regarded as an undulatory motion. He has proved that it is transmitted through space devoid of ordinary matter, such as a complete vacuum, and he supposes that its undulations must be transmitted by a perfectly elastic imponderable medium. The existence of the medium is probable, because it is impossible to conceive the transmission of undulation without a medium to undulate.

The chemist also has recourse to a scientific use of the imagination. His molecules and atoms are creations of the imagination rendered necessary for the explanation of chemical phenomena. They serve so well to offer reasonable explanation of such phenomena that no one doubts their existence.

The physiologist is also obliged to use his imagination to carry him into the unknown regions of vital processes. His microscope cannot reveal the minutest structure of protoplasm; his chemical processes are insufficient to show the chemical actions that lie at the root of life; he cannot explain why the activity of the protoplasm of a liver cell is so different from that of a nerve cell. To in some measure meet the difficulty, he imagines that the molecular structure and chemical composition of the different cells is to be regarded as the cause of the difference in their vital manifestations. It is a mere hypothesis that serves to fill the void of the unknown acceptably, because it is harmonious with speculations to which the chemist and the physicist have been compelled to resort.

Or again, take as illustration of the scientific use of the imagination the celebrated theory of colour sensation advanced by Thomas Young. Convinced as he was so strongly that light is an undulatory motion, he imagined it impossible that the terminals of the optic nerve in the retina could respond to all the different frequencies of undulation contained in the visible rays of light. He imagined it more reasonable to suppose that the apparent continuity of the spectrum as seen by a normal eye may be explained by supposing that the optic terminals contain only three sets of particles, two of them specially thrown into vibration by the undulations near the ends of the spectrum, and the third specially by intermediate undulations. He proposed to reduce primary colour sensations to three in number—red, yellow, and blue, or red, green, and violet, and to derive other colour sensations from their admixture. He expressed the opinion that his suggestion “simplified the theory of colours, and might, therefore, be adopted with advantage until found inconsistent with any of the phenomena.” In these few words taken from Young’s writings you find a definition of the limits that must bound a scientific use of imagination. A hypothesis may be adopted with advantage if it serves to furnish an explanation of obscure facts, but must be abandoned if the advance of knowledge proves it to be “incon-

sistent with any of the phenomena." Few efforts of scientific imagination have induced so much research by the physicist and physiologist to prove or disprove the adequacy of such a hypothesis as Young's speculation regarding colour vision.

Scientific imagination strives to penetrate the unknown, not vaguely, as in a confused dream, but by circumspectly searching for some opening to admit light, and always returning to the citadel of ascertained truth to test the reasonableness of its speculations.

Scientific imagination has always been the parent of *invention*, and it has also been, in the great majority of cases, the pioneer of *discovery*. Pasteur's method of treating anthrax and hydrophobia was the brilliant result of a powerful scientific imagination penetrating the unknown, and eventually discovering that its preconceptions had been well founded.

But, perhaps, some of you will say, Have we really anything to do with imagination? We are come here to learn what is already known, and not for the purpose of attempting to make discoveries. I tell you that you cannot learn physiology aright unless you have imagination enough to carry you from its visible processes to the invisible activities of molecular mechanisms in which the mysteries of life lie hid. And who of you can tell whether or not you will, on some future day, make additions to scientific knowledge. No year passes without discoveries being made by graduates who were students the other day. You had better not live in the hope of stumbling on some important discovery; for new truths are seldom arrived at in that way. The first condition necessary is the formation of the *idea* that is to initiate and direct the research. Discoveries are comparatively rare, not merely because it is difficult to prosecute research, but far more because originality of idea is so exceptional. None of you can tell what original ideas may arise in the mind in the course of your ordinary study. One cannot summon up such ideas by command, but we can, all of us, strive to render our studies as thoughtful as possible. That is the secret of the signal success achieved by some in student days, and afterwards in medical practice.

Critical discussion of the theories of medical science is the most powerful incentive to thoughtful study. It compels a man to make up his mind, and formulate definite opinions as the result of his own independent judgment. The bane of physiology and of medicine in former times was, that most men had not the courage to think for themselves. They bowed to the authority of Galen as if he had been an infallible demi-god, just as men in the non-scientific world of our time implicitly follow certain leaders, because they have not the courage to think for themselves and avow their opinions.

The whole range of medical science abounds with topics suitable for discussion. I would advise every student to find some congenial friend who will daily discuss with him the problems that arise in

the course of study. The daily sharpening of the iron by the friction of mind with mind is one of the most valuable features of such collective life as exists in a University.

But private discussion with a friend is not sufficient to evoke the highest efforts of critical thought; discussion in the assembly is necessary. Let me advise every student who is entering on his third year of study to join a Society for the discussion of medical topics. So far as I know, no other Medical School in the world has a Student's Society at all approaching our Royal Medical in the many advantages it offers. The most thoughtful students have generally been found there. I have heard many a man express his gratitude to that Society for the extent to which it had contributed to his success in after life; and I have also seen how much some men have lost by not having in student days had their critical faculty developed by joining such a Society. I have not unfrequently heard a student say that he had no time to join a debating society, because it takes too much time from the work required for examinations. Many are under that idea, because they have not by experience realised that a single evening spent in discussion each week, so brightens and sharpens the intellect, that better mental work is done on all the other days; and they are also unaware how much greater effect would be given to their study by increasing their insight and critical power.

I trust the thoughts I have placed before you on this our opening day may prove serviceable in helping you to pursue your studies throughout the Session, in such a manner as will bring credit to us all and ultimate success to you.

